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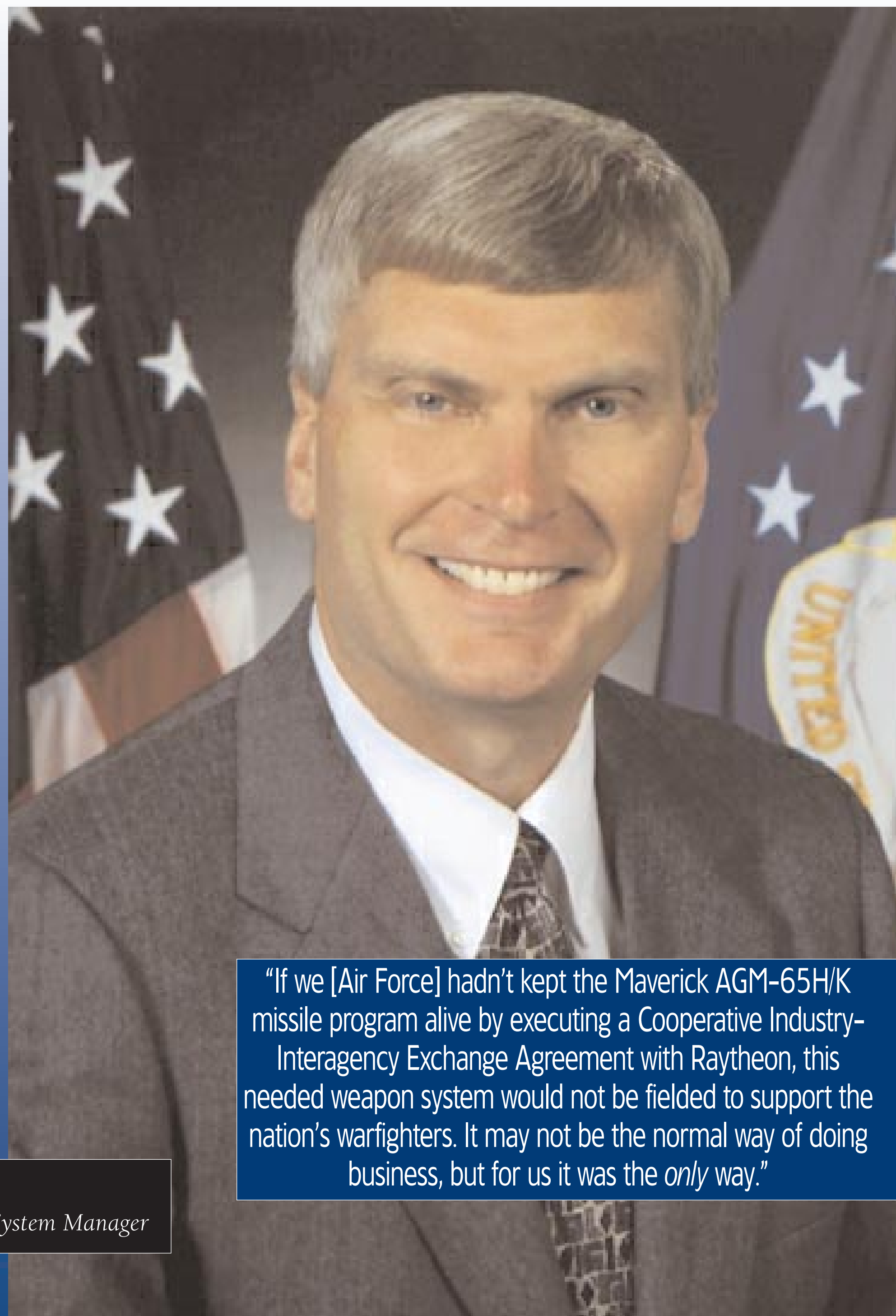


"If we [Air Force] hadn't kept the Maverick AGM-65H/K missile program alive by executing a Cooperative Industry-Interagency Exchange Agreement with Raytheon, this needed weapon system would not be fielded to support the nation's warfighters. It may not be the normal way of doing business, but for us it was the *only* way."

Marc Trinklein
Maverick AGM-65H/K Development System Manager

A Bimonthly Magazine of the Defense

PROGRAM MANAGER

Vol XXVIII, No.5, DSMC 152

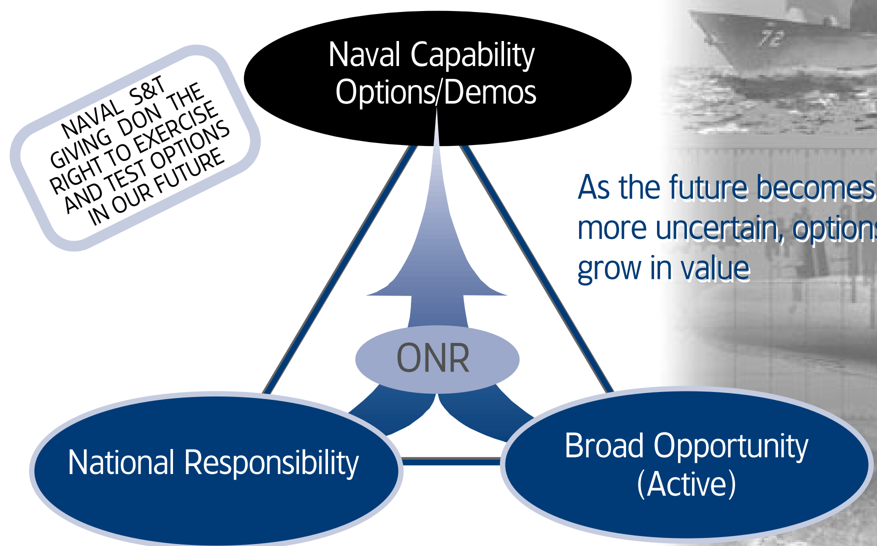
Science and Technology From An Investment Point of View

How ONR Handles Department Of the Navy's Portfolio

REAR ADM. PAUL GAFFNEY, U.S. NAVY
DR. FRED E. SAALFELD • JOHN F. PETRIK

Anyone interested in science and technology policy will recognize a familiar dilemma: Should you support basic research and hope for revolutionary breakthroughs and long-term payoffs, or do you go for evolutionary applied work that will show fast results? In some respects, the dilemma posed by this question is a false one. The Office of Naval Research (ONR) probably has as much experience wrestling with this question as any American federal institution, and we think we have an approach to science and technology that offers our ultimate shareholders — sailors and Marines — the best return on investment we can give them (Figure 1).

FIGURE 1. **Naval Science & Technology Investment Balance**



Science and Defense

Between 1946 and the founding of the National Science Foundation in 1950, ONR was the federal government's only agency whose principal mission was the support of basic research. For a brief period, university researchers were able to draw upon extensive government funding without struggling with demands that their work be justified in terms of quick benefit to the taxpayer. In those immediate postwar years, several historical accidents came together to produce a climate of public opinion in which support for pure science was relatively uncontroversial. Americans credited big science, pure science, with having done much to win the war. Indeed, even given the traditional American fascination with invention, progress, and technology, World War II forced technical and scientific advance into popular thinking about defense to an unprecedented extent. People remembered Pearl Harbor and never wanted to be surprised like that again, and saw technology as a guarantor of security.

Basic science shared the aura of victory. There was sufficient grant and contract money available as a legacy of wartime research, and academic scientists had grown accustomed to doing government work. Such ready and unproblematic support was as short-lived as it was unprecedented. It is unlikely to return soon.

The original permanent basic research establishment, ONR has evolved over the last 53 years into something more diversified and, in some respects, more accountable to its customers than its founders envisioned. The greatest change occurred in fiscal year 1992, when the Office of Naval Technology (ONT) and the Office of Advanced Tech-

__Gaffney__ became the 19th Chief of Naval Research, commanding the Office of Naval Research (ONR), July 12, 1996. His biography appears on p. 14. __Saalfeld__ was appointed Technical Director of ONR and Deputy Chief of Naval Research in 1993, where he is responsible for the Navy and Marine Corps science and technology program, including basic research, exploratory and advanced technology development conducted in federal and private laboratories, academia, and industry. Saalfeld received his B.S. degree cum laude with majors in Chemistry, Physics, and Mathematics from Southeast Missouri State University in 1957. He was awarded his M.S. and Ph.D. degrees with a major in Physical Chemistry and minors in Inorganic Chemistry and Mathematics from Iowa State University in 1959 and 1961, and remained one year at Iowa State as an Instructor. __Petrik__ works for Noesis, Inc., a consulting firm based in Virginia, and supports ONR. A major in the U.S. Army Reserve, he served on active duty for 12 years in a variety of field artillery assignments. He holds a bachelor's degree from Middlebury College and a master's from the University of Chicago, and has taught at the U.S. Military Academy and Rockhurst College.

nology (OAT), separate agencies that reported to the Chief of Naval Research, were folded into ONR. With the absorption of ONT and OAT, ONR was reinvented and became responsible for applied research and technology development.

Since then, ONR has worked to integrate the research it supports and to produce an investment portfolio that does justice to its several constituencies: Congress, the Fleet, the Force, industry, and universities.

The Move to Integration

As their names imply, ONT and OAT had been responsible for research that had a clear and relatively short-term payoff: hull coatings, radar masts, missile control surfaces, and the like. Development of such items falls into the Department of Defense budget activities known as 6.2 and 6.3 funding: applied research and advanced technology development respectively.

ONR, by contrast, had been largely involved with 6.1 funding – basic research. Roughly speaking, in the Department of Defense lexicon, *basic* research seeks to advance understanding of fundamental aspects of processes and properties. *Applied* research seeks ways of altering, manipulating, or using those processes and properties in such ways as may meet a specific, recognized need. Advanced technology development, finally, involves taking the results of applied research and actually fabricating things that perform some useful function, that provide some desirable capability.

Higher-numbered budget activities – 6.4 and up – no longer belong to the administrative and budgetary worlds of science and technology proper, but rather to acquisition, operations, and maintenance, among others. They lie outside the scope of this discussion, but it should be borne in mind that results from 6.1, 6.2, and 6.3 must ultimately transition projects to those other categories if the program is to succeed.

The picture the budget activities suggest when one lays them out like this, is an eminently rational one. Each level hands on the product to the next for refinement in a smooth, linear, efficient progression – a kind of assembly line that mills concepts into hardware. In fact, however, the research enterprise is so notoriously difficult to integrate in such a straightforward manner that counsel against naive optimism is common.

Nobel laureate Joshua Lederberg is quoted among research managers as advising that, "The best way to achieve scientific progress is to resist the temptation to control it."[1] Paul Nitze, as Secretary of the Navy in the mid-1960s, encountered the perennial challenge of showing that research pays by demonstrating that basic work actually generated some particular weapon, tool, or system.[2] He talked about this when he addressed ONR's 20th Anniversary celebration in 1966:

"I would note that the exercise of actually attempting to trace such parentage is often more academic than fruitful, for the trace quickly becomes dim and no rational sequence seems to prevail. This is inevitably the nature of creative ideas, basic answers, and basic data for which – once we have them – applications are seen. Yet data by themselves are sterile; it is the ephemeral idea that makes them useful."

Nitze's words were by no means a counsel of despair, and were not taken as such. ONR's assumption of responsibility for basic research, applied research, and advanced technology development suggested anew that efficiencies might be realized from vertical integration. If work supported from all three budget activities – 6.1, 6.2, and 6.3 – could become mutually supporting, all of the customers would win.

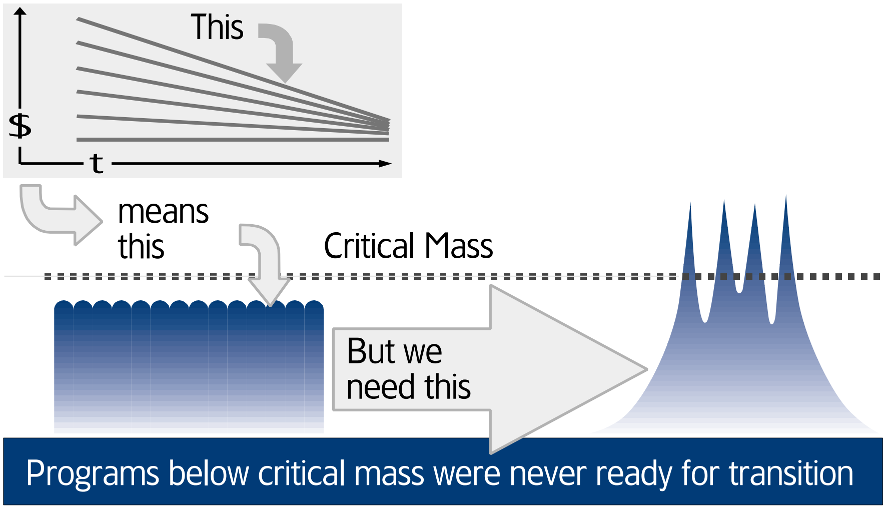
Appropriate agents of such integration are the staff scientists who serve as its project managers. They have the appropriate technical expertise and scientific credibility to administer awards and recognize quality – in the marketplace of science and technology, they are the Navy's ultimate smart buyers.

As the first step toward "reinventing" itself, ONR integrated appropriate 6.1, 6.2, and 6.3 programs to enhance connectivity within the Department of the Navy's science and technology programs.

Future naval mission capabilities were identified by senior naval management. These capabilities were analyzed, and divided into prioritized enabling capabilities by the naval requirements community. Those enabling capabilities were then analyzed by the science and technology community into five areas:

- Capability Gaps
- Capability Specifications
- Key Technologies
- Current National and International Programs

FIGURE 2. **Science & Technology Problems**



REAR ADM. PAUL G. GAFFNEY II, U.S. NAVY

Chief of Naval Research

Rear Adm. Paul G. Gaffney II became the 19th Chief of Naval Research, commanding the Office of Naval Research (ONR), effective July 12, 1996. As Chief of Naval Research, he manages the science and technology programs of the Navy and Marine Corps, from basic research through manufacturing technologies. Gaffney assumed additional duties as Director, Test and Evaluation and Technology Requirements, May 1998, and was appointed Assistant Deputy Chief of Staff for Science and Technology, Headquarters, U.S. Marine Corps, November 1998.

His distinguished military career spans nearly three decades and includes duty at sea, overseas and ashore in executive and command positions. His duties have included tours as: Operations Officer in *USS Whippoorwill,* a minesweeper homeported in Sasebo, Japan; Advisor to the Vietnamese Navy Combat Hydrographic Survey Team; Executive Assistant to the Oceanographer of the Navy, Washington, D.C.; Commanding Officer of Oceanographic Unit Four conducting hydrographic surveys in the Republic of Indonesia; Military Assistant to the Assistant Secretary of Defense (International Security Affairs); Commanding Officer of the Naval Oceanography Command Facility, Jacksonville, Fla.; Assistant Chief of Naval Research in Washington, D.C.; Commanding Officer of the Naval Research Laboratory in Washington, D.C.; and Commander, Naval Meteorology and Oceanography Command.

He is a 1968 graduate of the U.S. Naval Academy, was selected for immediate graduate education, and received a master's degree in Ocean Engineering from Catholic University of America in Washington, D.C. He also holds an M.B.A. from Jacksonville University. Gaffney completed a year as a student and advanced research fellow at the Naval War College, graduating with highest distinction.

- Assessment of Science and Technology Efforts Needed to Fill the Capability Gap.

These assessments were employed to build the necessary changes to the Department of the Navy science and technology program.

In order to ensure that its science and technology program meets its future capabilities' needs, the Department of the Navy has come up with a six-step decision-making process and established a four-star Department of the Navy Science and Technology Corporate Board to provide corporate management. This Board consists of the Vice Chief of Naval Operations, the Assistant Commandant of the Marine Corps, and the Assistant Secretary of the Navy for Research, Development and Acquisition.

Preserving Effectiveness — Showing Results and Making a Difference

Federal support for science and technology is no longer as flush as it was in the late 1940s. Budgets have declined in relative terms, particularly since the Vietnam War brought with it high operating costs and public disaffection with military-supported research. Even during the small renaissance the defense establishment enjoyed in the waning days of the Cold War, defense investment in research and development (R&D) had begun to be eclipsed by industry's investment in R&D. Budgets have remained tight during the retrenchments of the past decade.

One of us likes to point out that in 1999, the Department of the Navy's science and technology budget was $1.3 billion. Back in 1964 when he was in his plebe year at the Naval Academy and getting interested in a career in science and technology, that budget was a billion 1999 dollars larger — $2.3 billion. But during the last three decades, the Navy and Marine Corps have not seen a corresponding reduction in their mission requirements. If anything, expectations are higher today than they were in the early 1960s.

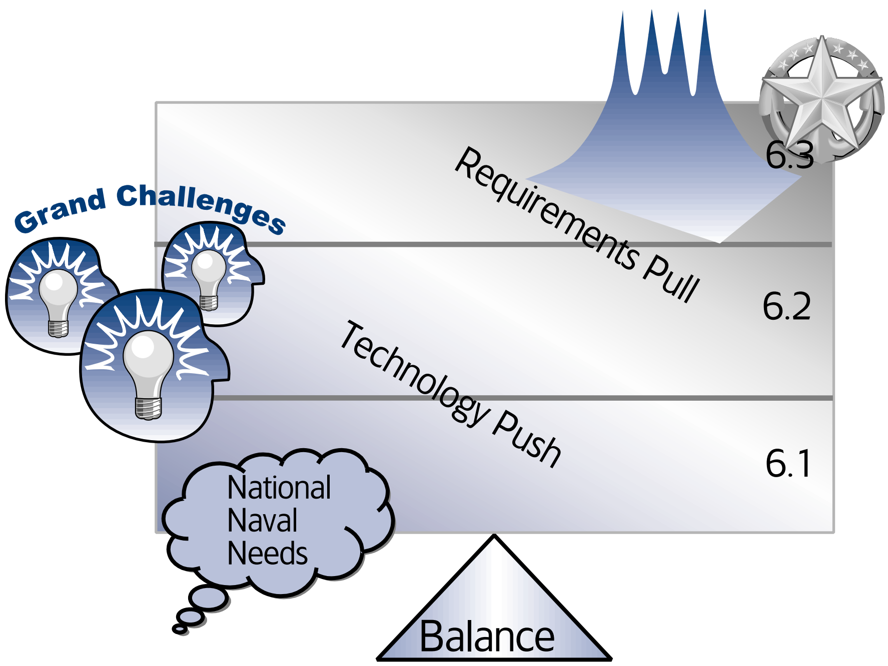
From An Investment Point of View

When resources decline, and if a number of different constituencies are still clamoring for a piece of the smaller research pot, there is a natural tendency to try to give every program's advocates a relatively equivalent but absolutely smaller portion of the available resources. Furthermore, because science and technology tend not to have an immediately visible payoff (it becomes very visible once it appears in operational systems, but those systems take time to emerge), its budget is always a tempting target for those seeking to trim expenditures. Neither of these moves makes sense from an investment point of view (Figure 2).

Instead, a sensible investment strategy would aim first and most obviously at stabilizing funding. Stable funding is essential to establishing a strong, solid 6.1 and 6.2 tech base. On this base, and only on this base, can one build an appropriately focused science and technology program that preserves a balance between longer- and shorter-term objectives (Figure 3).

Two important elements of the Department of the Navy's science and technology program that rest immediately on that tech base are the national naval responsibilities and the Science and

FIGURE 3. **Department of the Navy Science & Technology Investment Strategy — A Balanced Portfolio**



Technology Grand Challenges. National naval responsibilities are research areas like ocean acoustics that are essential to the Department of the Navy, but areas that no other mission agency or private enterprise can reasonably be expected to support.

The Science and Technology Grand Challenges, which help ensure that the Navy and Marine Corps are unlikely to be caught short 50 years hence, are a set of very difficult but probably achievable scientific and technical challenges ONR proposes to the research community. They are intended to be visionary, designed to meet what will in all likelihood prove to be compelling needs of the "Navy and Marine Corps After Next," and to afford many participants from a broad range of disciplines multiple opportunities for exciting, creative, risky research.

The national naval responsibilities and the Grand Challenges have an irreducible requirement for the highest-quality basic and applied research, and the Department of the Navy is determined to sustain the tech base that can provide it. This tech base is also the locus of what might be called "vision" – the ability of a program officer to recognize a promising line of research even before it has been summoned by a formally declared requirement. Such vision is more than serendipity.

For example, ONR's Dr. Mike Shlesinger saw the potential importance of chaos theory many years ago and had the vision to invest in this new (and then, high-risk) area. The Navy is currently well on its way to using the work he pushed in his capacity as a program officer to solving the problem of resupplying ships in heavy weather.

About half of the Department of the Navy's science and technology budget supports these longer-term efforts.

Delivering Capabilities

The tech base and the Grand Challenges are only half the balance. The other half of the balanced portfolio weighs in to produce capabilities for the warfighters who are the principal shareholders in the Department of the Navy's corporate science and technology effort.

An effective science and technology investment strategy must also provide prioritized naval and Marine capabilities. It should give the Department of the Navy options it can elect to exercise in response to its evolving missions, developed with the process previously described. This is where the investment focus sharpens, because research succeeds only when its resources reach a critical mass. To achieve that critical mass, one needs to identify a few crucial areas that can be pushed above critical mass (Figure 4).

When you try to fund everything, nothing gets over the bar except maybe by Brownian motion.[3] So rather than support every program with funding that falls short of the level at which research has a chance of being productive, the Department of the Navy has decided to concentrate its higher-category budget appropriations into future naval capabilities, and to have the Department of

FIGURE 4. **Forming Critical Mass for Science & Technology**

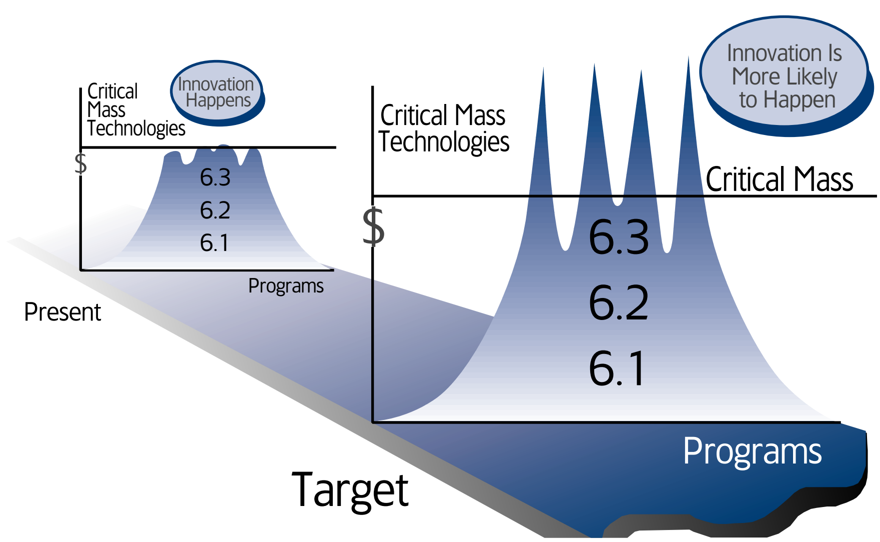
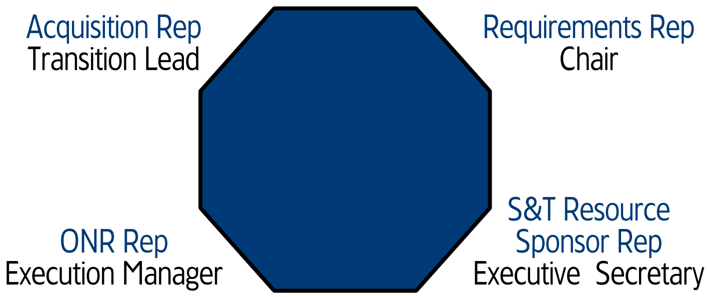


FIGURE 5. **Integrated Product Team Membership**



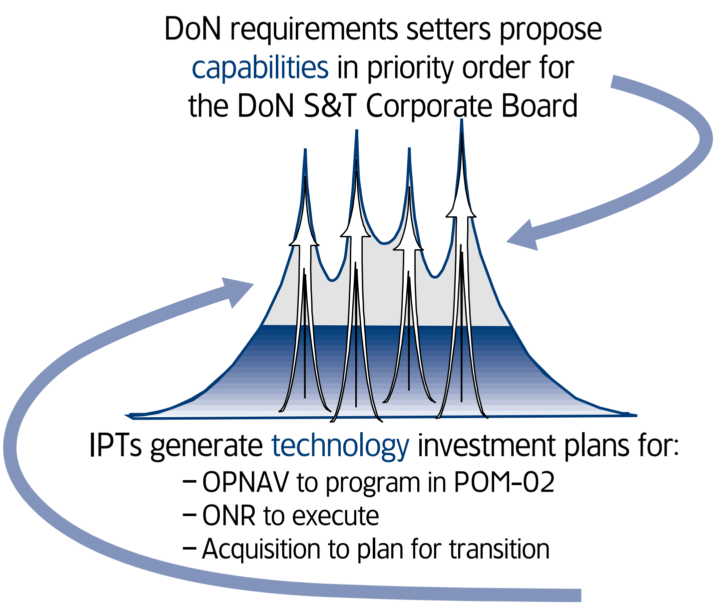
the Navy science and technology program respond to these capabilities with a series of "spike investments."

A spike investment is formally a science and technology program developed in response to prioritized, desired future Navy and Marine Corps capabilities.

Each naval capability is managed by an integrated product team (IPT) that functions like a corporate board (Figure 5). The integrated science and technology program – the "spike" – is developed by the science and technology representative to the IPT who functions like a company Chief Executive Officer producing the spike. The IPT will have the following members:

- **Chair.** The Chair comes from the Requirements Community (representing the Chief of Naval Operations, the Marine Corps Combat Development Command, the Fleet, and the Force). The Chair leads the IPT in defining and prioritizing capability goals, and in approving the investment plan presented by the Execution Manager for the Technical Working Groups.
- **Transition Leader.** This member comes from the Acquisition Community (representing the Systems Command, the Program Executive Office, or the Implementing Community). The Transition Leader is responsible for coordinating the transition path and acquisition decision points for technologies under development.
- **Execution Manager/Technical Working Group Leader.** This member is the Science and Technology Community representative. The Execution Manager/Technical Working Group Leader heads the IPT's Technical Working Groups. These working groups will arise after the capability priorities are set by the IPT and will then craft the investment plan for management and execution of the program. Requirements and Acquisitions representatives will be afforded membership in all Technology Working Groups. The investment plan will be approved by IPT consensus. In this role the Execution Manager will report to the IPT (acting in its capacity as the board of directors). The programmatic response (a spike) will have the following generic qualities:
  – It provides significant technology options and operating concepts to meet the Department of the Navy capability.
  – It has a significant budget, definite milestones and objectives, concrete deliverables, and a finite end state.
  – It culminates in well-defined demonstrations (or Fleet Battle Experiments or Amphibious Warfare Experiments) of the technology options.
- **Executive Secretary.** The Executive Secretary will serve as point of contact for the IPT, promulgate the agenda, and record results of IPT decisions. The Executive Secretary will be responsible for recording progress of the IPT on a monthly basis through spike approval by the Department of the Navy Science and Technology Corporate Board, and quarterly thereafter (Figure 6).

FIGURE 6. **The "Pull"**



Picking Capabilities, Managing Spikes

As we noted earlier in this article, the Department of the Navy does not select capabilities in a vacuum. The IPTs nominate capabilities to the Department's Science and Technology Corporate Board. Because the requirements community, the acquisition community, and the science and technology community all contribute members to these teams, establishing an IPT for each naval capability helps ensure that the right capabilities are considered. The approval of spikes in response to these capabilities at the highest levels helps ensure that they receive the support they need if the investment strategy is to succeed.

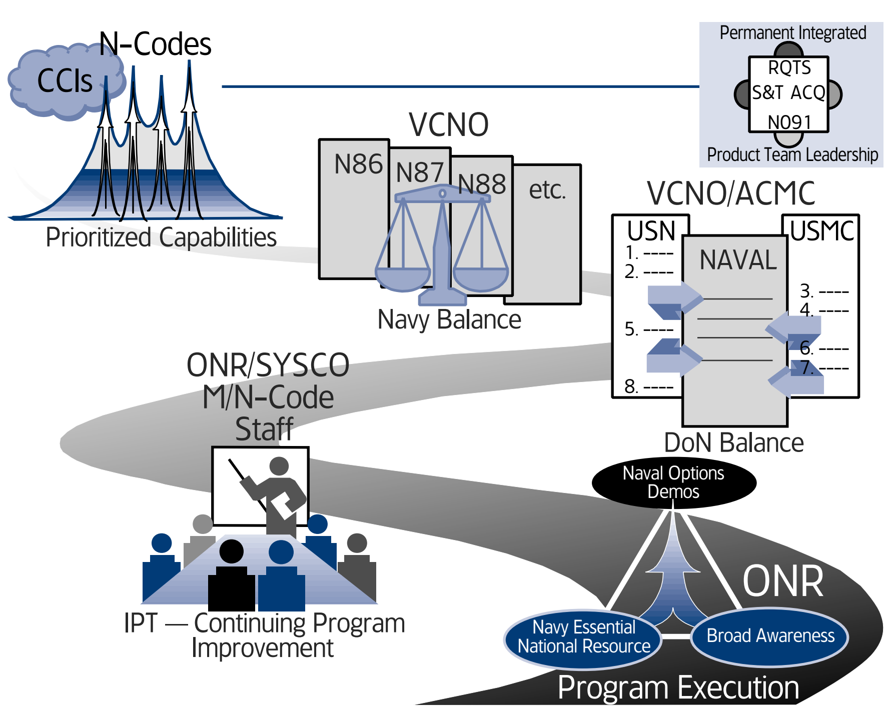
The First Spikes

The first spikes reflected this approach. Initially there were three: Organic Mine Countermeasures, Destroyer Technology, and Extending the Littoral Battlespace. As the Department of the Navy continues to fill out its science and technology investment portfolio, it has generated a list of future capabilities that will either subsume or add to the existing capabilities:

- Organic Mine Countermeasures
- Information Distribution, which now includes an Advanced Concept Technology Demonstration – Extending the Littoral Battlespace
- Time-Critical Strike
- Decision Support System
- Autonomous Operations
- Littoral Antisubmarine Warfare
- Total Ownership Cost Reduction
- Missile Defense
- Platform Protection
- Expeditionary Logistics
- Warfighter Protection
- Capable Manpower.

These are candidate future capabilities, and will provide the leadership of the Navy and Marine Corps with an appropriate set of technological options as they look to ensuring that the operating forces maintain their winning edge in the first decades of the next century (Figure 7).

FIGURE 7. **The New Process**



Smart Buyer, Smart Investor

The Department of the Navy's new acquisition strategy depends upon the Department's being a smart buyer – or better yet, a smart investor – and it can only be smart as long as it hangs onto vital scientific and engineering expertise in places like ONR and NRL. This insight is not a new one. Secretary Nitze expressed it more than 30 years ago in his anniversary talk:

"We must, therefore, remain in a position to influence and stimulate thinking in the scientific community along lines of ultimate Navy relevance. We must have our own contacts with that community, as must – needless to say – other branches of the government."

The Department of Defense is charged by the president with helping him discharge his constitutional responsibility for the common defense. Part of that responsibility remains knowing what is needed to defend the nation, and that knowledge has to drive investment in science and technology. Controlling the process that determines what those investments will be seems inherently part of that responsibility.

It is difficult to imagine circumstances under which government might abdicate these responsibilities to industry. That is not because industry is unpatriotic, grasping, or untrustworthy – it is none of these things. It is rather because the executive branch is responsible for national defense, and that cannot be outsourced. Moreover, the government is supposed to speak for America. Industry inevitably and rightly has a narrower perspective, yet one that should fit consistently into the larger context of national interest. So ultimately, the Department of the Navy cannot delegate its research portfolio.

As the manager of the Department of the Navy science and technology program, ONR will continue to ensure that the portfolio includes the best available mix of investment partners and research performers. And since our ultimate shareholders are sailors and Marines, the return on investment we look for in naval science and technology is not *profits*, but *capabilities*.

Editor's Note: The authors welcome questions/comments on this article. Send an E-mail to **petrikj@onr.navy.mil.**

REFERENCES

1. Joshua Lederberg won The Nobel Prize in Physiology/Medicine in 1958 for his discoveries concerning genetic recombination and the organization of the genetic material of bacteria.

2. President John F. Kennedy appointed Paul Nitze the 57th Secretary of the Navy in November 1963, a position he held until July 1967.

3. Brownian Motion is constant, erratic movement of tiny particles suspended in a fluid/gas, a phenomenon discovered in 1827 by British botanist Robert Brown.